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INFORMATION CIRCULAR

ASBESTOS - MILLING, MARKETING, AND FABRICATION

BY

OLIVER BOWLES

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ASBESTOS - MILLING, MARKETING, AND FABRICATION[1]

By Oliver Bowles[2]

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U.S. Bureau of Mines Information Circular 6869.

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INTRODUCTION

This paper is the third of a series of reports on asbestos prepared by the Bureau of Mines. The reports already issued contain general information, including descriptions of deposits throughout the world.[3] The present paper deals chiefly with milling and marketing. Many grades of asbestos are marketed and an important phase of milling is the grading of fiber; these subjects therefore are related so intimately that contiguity in their treatment is fully justified. Although the Bureau of Mines is interested primarily in the mining and preparation of raw materials, the fabrication of asbestos products has attained such importance in the United States that brief reference to processes of manufacture is included.

CLASSIFICATION OF FIBER

Canadian asbestos fibers are divided into three main groups - crudes, mill fibers, and shorts. The term "crude" is applied to fiber of spinning grade measuring three eighths inch or longer, that is hand-cobbed and not passed through a mill. Mill fibers are obtained by crushing and beating the fiber-bearing rock until the asbestos is freed and then removing the fiber from the rock by screening or air separation. Shorts are the lowest grades of mill products.

Russian asbestos also is classed as crudes and mill fibers, but the term "crude" is applied somewhat loosely; it apparently includes some spinning fiber that has been prepared mechanically.

This term is not generally applied to African products. Spinning fibers comparable in quality with Canadian crudes are prepared by hand-cobbing alone or in conjunction with simple mechanical crushing, disintegrating, and screening processes. A much larger proportion of the African long fibers have been prepared mechanically during recent years. Mill fibers of the shorter grades constitute the largest part of the tonnage.

PREPARATION OF FIBER FOR MARKET

General Features of Milling Methods

As pointed out in an earlier report the two major types of chrysotile occurrences are (1) deposits derived from alteration of peridotite-pyroxenite rocks and (2) deposits derived from dolomitic limestone intruded by diabase. The first type is the principal source of asbestos in Vermont, Quebec, the Ural Mountains, Rhodesia, and the Transvaal. The second type, which has little commercial value, occurs in Arizona; Minusinsk, Siberia; and the Carolina

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3/ Bowles, Oliver, Asbestos - Domestic and Foreign Deposits: Inf. Circ. 6790, Bureau of Mines, 1934, 24 pp.; Asbestos - General Information: Inf. Circ. 6817, Bureau of Mines, 1935, 21 pp.

district of South Africa. The principal gangue material associated with asbestos of the first type is serpentine, and the materials with the second type are serpentine and limestone. As chrysotile also is serpentine, differing only in structure from the gangue, it is obvious that the milling of chrysotile must differ from all other forms of ore concentration. As the valuable mineral and the gangue consist of the same material, neither chemical composition nor specific gravity can be utilized as the basis for separation. The property that makes mechanical separation of chrysotile possible is its fibrous structure, which permits it to be opened or divided by impact into separate filaments, thus making it amenable to separation from the gangue by air suction and screening.

The value of chrysotile asbestos depends largely on the length of the fiber. When fiber three eighths inch long is worth $100 a ton fiber three fourths inch long is worth approximately $400 a ton. Thus it is apparent that breaking fibers in half destroys approximately three fourths of their value. The most important principle underlying the milling of asbestos therefore is the separation of fiber from rock with minimum breakage of fibers. The best machines spare the fiber unnecessarily rough treatment and at the same time break the rock effectively. Modern mills are designed to remove the separated fiber after each crushing process, to separate the sand as soon as it is formed, and to keep hard, barren rock out of the mill. If fiber already freed from rock enters the next crushing unit along with sand and rock fragments, it will be broken into shorter grades. Asbestos milling consists essentially of coarse crushing, drying, and recrushing in stages, each step being followed by screening and air separation of fiber from rock.

Another peculiarity of asbestos milling is the absence of any known method of testing the quality of mill feed. A rock that appears to contain little fiber may yield a fair return; conversely, one that appears promising may show a disappointingly low recovery. As both the valuable mineral and the gangue are serpentine an assay is useless. A laboratory-scale crushing and fiber-separating unit might give results that differ widely from those of a commercial mill operating on the same rock. Although the percentage of recoverable fiber in a rock cannot be determined in advance the actual yield can be calculated from the mill output.

In the following discussion of milling methods throughout the world Canadian practice is considered first, because Canadians were the pioneers in the asbestos industry, and their methods have established a basis for practice in other countries.

Canada

Preparation of Crudes

In Canada the associated rock is broken free of the larger-fiber veins by sledging, and the masses of fiber are sorted by hand. The fiber with some adhering rock is dried on steam coils and then taken to the cobbing sheds where the fiber veins are flattened with a hand hammer, freeing them from adhering rock. The separated rock, dust, and short fibers are dropped into a receptacle under the bench, and the remaining high-grade fibers are classed as Crude No. 1, material 3/4 inch long and over, and Crude No. 2, material 3/8 to 3/4 inch long. To separate further the short fiber and rock dust, Crude No. 1 is screened on a flat shaking screen with 3/8-inch holes and No. 2 on one with 3/16-inch holes. After being screened the fibers are bagged in jute bags of 100 pounds capacity. Five to twenty percent of the rock fragments, dust, and short fiber still remain in the crudes as sold, and these impurities are separated at the factory where asbestos products are manufactured. Rejects accumulated in preparing crudes are utilized as mill fibers or sold as screenings. Crudes constitute a small proportion of the recoverable fiber but are the most valuable products.

Ru Keyser has developed a process of preparing long fiber mechanically, by which rolls are used instead of hand hammers.[4] The fibers are graded on screens which are so operated that the fibers are held in a horizontal plane. The claim is made that fibers thus prepared are superior in grade and purity to hand-cobbed crudes.

Milling Practice

Primary crushing. - Rock from the quarries or mines is dumped into a so-called "sluice" that holds several carloads. The sluice may have a railroad-rail-grizzly bottom which provides a bypass for fines. The primary-crusher feed from the sluice is controlled by finger gates, that is, suspended rails which may be moved up or down. A jaw crusher with a 36-inch by 24-inch opening set for a 4- to 6-inch discharge is the most popular primary breaker. Larger or smaller units may be employed as needed.

Sorting. - The crusher discharges to a picking belt to remove liberated crudes.

Drying. - The quarry rock contains considerable moisture, in winter even snow and ice, and it must be dried for proper milling. Standard rotary driers generally are used. The shells are 40 to 60 feet long, 4 to 6 feet in diameter, and inclined at an angle of 7°. The material is lifted by a series of blades and allowed to fall through the current of hot air that circulates through the cylinder. Capacities range from 30 to 60 tons of rock an hour and costs from 4 to 18 cents a ton.

Stack driers also are used and said to be much more economical. Rock is elevated to the top of a 50-foot stack 7 feet in diameter and allowed to fall through a rising current of hot air. Grid bars interrupt the speed of the descent.

Storage. - A large supply of rock in storage insures regular mill feed. Rock is fed to the mill on belt conveyors carried in concrete tunnels beneath the storage bins. By drawing rock from several gates at the same time material of comparatively uniform size and fiber content is obtained. Bins having capacities of 25,000 to 150,000 tons are in use.

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[4] Ru Keyser, Walter A., Mechanical Cobbing of Chrysotile Asbestos: Eng. and Min. Jour., vol. 134, no. 6, June 1933, pp. 235-237.

Fiberizing, screening, and air separation. - Although crushing, drying, and storing methods are fairly uniform throughout the Canadian district milling methods vary greatly. No flow sheet can be applied generally because milling must be modified to suit the rock. A method suitable for hard rock would be too severe for fiber enclosed in soft rock. Secondary crushing may be done with jaw or gyratory crushers, rolls, Symons cones, or hammer mills. A straight impact that frees and fluffs the fiber is preferred to a grinding or shearing action. Rolls therefore are less desirable than impact mills.

The following flow sheet given by Ross[5] probably represents the best modern practice.

Grizzly in rock sluice
Jaw crusher
Drier
Grizzly, fines to screens fitted with suction
Gyratory crusher
Screens with suction
Rolls
Screens with suction
Jumbo
Screens with suction
Jumbo
Screens with suction
Jumbo
Screens with suction
Jumbo
Screens with suction
Rotary graders and flat cleaning screens
Floats bin
Sand to dump

It will be observed that the principle of removing fiber after each stage of crushing is followed strictly.

According to this flow sheet crushing beyond the primary stage is accomplished with gyratory crushers and Jumbo machines. The Jumbo, which is manufactured locally, is a horizontal drum 6 to 8 feet long and 24 to 30 inches in diameter. Beaters attached to a horizontal shaft consist of arms that support manganese-steel hammers. The beaters are set at intervals of 6 or 8 inches along the shaft and clear the inside of the shell by about 1/2 to 1 inch. They are turned at an angle to direct the broken rock toward the discharge end. The shaft rotates at 400 to 800 r.p.m., according to the nature

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[5] Ross, J. G., Chrysotile Asbestos in Canada: Canada Dept. of Mines Bull. 707, 1931, p. 42

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of the rock treated. Instead of the Jumbo machine some mills employ various types of cyclones, which beat the rock to a powder. The Laurie cyclone consists of a cast-iron chamber in which two beaters shaped like ship propellers are driven in opposite directions at a speed of 1,700 to 2,000 r.p.m. In the Pharo cyclone the beaters revolve in the same direction, and the rate of discharge is controlled by gates. The Torrey cyclone is somewhat like the Jumbo, except that the axis of the beater arms is vertical.

Shaking screens generally are used, although vibrating screens of the Hum-mer type also are employed. Fines pass through the screen, but the coarser rock fragments and longer fiber remain on the screen. The shaking action brings the fiber to the surface of the bedded-rock fragments; at the discharge end of each screen the fiber is lifted and removed by suction. The opening of the suction hood is 3 to 4 inches wide and extends across the full width of the screen. Thus, each screen furnishes three products - fines that pass through as waste, coarse rock fragments discharged at the end, and fiber collected by the suction fan. Oversize fragments pass to the next fiberizing unit.

The fiber is carried through pipes to a collecting chamber, where the diminished rate of the air current permits it to fall. The dust-laden air from the fans is blown into chambers, where the fine fibers are collected as "floats."

Wet process. - Considerable progress has been made in developing a wet process for treating Canadian asbestos. Some claim that wet treatment involves less breakage of fiber and a higher recovery. Experiments were begun in 1921, and a testing plant was built in 1923, but commercial usage has not been attempted.

Grading. - Fiber usually is graded according to length in trommels 3 to 5 feet in diameter and 5 feet long fitted with woven-wire cloth. A central shaft is equipped with wooden paddles that agitate the fiber and force the shorter grades through the screen mesh. One type is a stationary trommel in which the paddles rotate at 600 to 800 r.p.m. Another type rotates in one direction at 5 r.p.m., and the paddles rotate in the opposite direction at 180 to 250 r.p.m. Some trommels make only one finished grade - that passing through the screen - and the oversize is conducted to a second trommel for further grading. Thus, several trommels may operate in series. At one of the newer mills the trommel is equipped with 2 sizes of screen cloth, which make 1 oversize and 2 undersize grades. Any number of grades may be made, and special grades may be obtained by blending. Sand and dust are removed from the graded fiber on flat cleaning screens. Finished fiber lifted from the cleaning screen by air suction is conveyed to the store room for bagging.

Classification of Fiber

Methods of grading asbestos fiber by length have been described in a preceding section. To determine with reasonable accuracy the quality of fiber in each grade and thus be able to modify grading methods accordingly, a standard testing machine is used. The purchaser can rely on the standard test and thus avoid any confusion that might ensue from dependance upon trade names or designations. A description of the Standard testing machine[6] follows:

> The machine consists of a nest of 4 wooden boxes, measuring 24-1/2 by 14-3/4 inches and 3-1/2 inches in depth. The boxes, which are superposed one above the other, are numbered from the top down 1, 2, 3, and 4. The bottoms of boxes nos. 1, 2, and 3 are made of metallic screen of the following specifications: Box no. 1: 1/2-inch opening, diameter of wire, 0.105 inch. Box no. 2: 4-mesh wire, 0.063 inch. Box no. 3: 10-mesh wire, 0.047 inch. Box no. 4 is a receptacle for the fines which fall through the three other boxes. The nest of 4 boxes or trays rests on a table to which an eccentric with a throw of 25/32 inch gives a movement of 1-9/16-inch travel.
>
> To made a test, 16 ounces of asbestos is put on the top tray which is covered. The machine is run at the rate of 300 r.p.m. at the shaft of the eccentric, and by means of an automatic device this is kept going for exactly 2 minutes, giving the nest a horizontal shaking movement. At the end of this time the asbestos which remains on each tray is weighed. This gives the grades of the asbestos fiber; the longest fiber naturally stays on the top tray, whereas the shorter fiber, according to its length, remains on screens 2 and 3 or drops into the pan or lowest tray. The more fiber retained on the first screen and the less fiber in the pan, the higher the grade and therefore the greater its value. If, for instance, a customer buys spinning fiber of the specification 4-7-4-1, it means that in a sample of 16 ounces, representing the average of the lot shipped, 4 ounces will remain on the top screen, 7 on the second, 4 on the third and finally 1 ounce will go through all the screens into the pan. He will evidently pay more for this material than for paper stock testing 0-0-10-6. This indicates that out of 16 ounces tested nothing is retained on the first 2 screens, 10 ounces remain on the third, and 6 ounces go through the latter into the pan. It is evident that the figures of the test represent the proportion in ounces of the different lengths of fiber in a pound of asbestos.

Samples for testing usually are taken at the grading machines every half hour. Owing to unavoidable variations in fiber as it comes from the pit, the quality of mill-run fiber usually is maintained a little higher than its designation.

6/ Ross, J. G., work cited, p. 49.

For many years each Canadian company graded its fiber according to its own standards and sold the products under its own trade designations. This practice led to much confusion in marketing, because different mills employed similar marks for grades quite unequal in quality and value. It was frequently necessary for buyers to have samples tested before placing orders. In 1931 producers in Quebec agreed upon a uniform classification of fibers, whereby they are divided into nine groups, and each group divided into grades. Crude asbestos was defined as "hand-selected cross-vein material essentially in its native or unfiberized form," and milled asbestos as "all grades produced by mechanical treatment of asbestos ore." Except for the very lowest grades, which are based on the weight per cubic foot, all milled grades are based on the results of tests in the standard testing machine previously described. Ross[7] gives a complete description of the standard grades of Canadian asbestos as agreed upon in 1931:

Crude asbestos

Class	Standard designation of grade	Description
Group No.1	Crude No.1	Consists basically of crude 3/4-inch staple and longer.
Group No.2	Crude No.2	Consists basically of crude 3/8-inch staple up to 3/4-inch.
	Crude run-of-mine	Consists basically of unsorted crudes.
	Crudes sundry ...	Consists of crudes other than above specified.

Milled asbestos

Group No.3	Spinning or textile fiber ...	Consists of fiber testing 0-8-6-2 and over.
Group No.4	Shingle fiber ..	Consists of fiber testing below 0-8-6-2 to and including 0-1½-9½-5.
Group No.5	Paper fiber	Consists of fiber testing below 0-1½-9½-5 to and including 0-0-8-8.
Group No.6	Waste, stucco or plaster.......	Consists of material testing below 0-0-8-8 to and including 0-0-5-11.
Group No.7	Refuse or shorts	Consists of material testing 0-0-5-11 and below, including material testing below 0-0-1-15 and specified as weighing 35 pounds or less per cubic foot, loose measure.
Group No.8	Sand	Consists of such asbestos mill products as sand weighing over 35 pounds per cubic foot, loose measure, and under 75 pounds per cubic foot, loose measure and containing a preponderance of rock.
Group No.9	Gravel and stone	Consists of such asbestos mill products weighing 75 pounds and over per cubic foot, loose measure.

(Continued on next page.)

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[7] Ross, J. G., work cited, pp. 50-51.

Subdivision of the groups of milled asbestos

Group no.	Standard designation of grades	Guaranteed minimum shipping test
No. 3: Textile and spinning fibers	3D	8 - 6 - 1 - 1
	3F	7 - 7 - 1½ - ½
	3K	4 - 7 - 4 - 1
	3M	2 - 9 - 4 - 1
	3R	2 - 8 - 4 - 2
	3T	1 - 9 - 4 - 2
	3Z	0 - 8 - 6 - 2
No. 4: Shingle fibers.............	4D	0 - 5 - 10 - 1
	4F	0 - 3 - 12 - 1
	4K	0 - 4 - 9 - 3
	4M	0 - 4 - 8 - 4
	4R	0 - 3 - 9 - 4
	4T	0 - 2 - 10 - 4
	4Z	0 - 1½ - 9½ - 5
No. 5: Paper fiber................	5D	0 - ½ - 10½ - 5
	5F	0 - ½ - 9½ - 6
	5K	0 - 0 - 12 - 4
	5M	0 - 0 - 11 - 5
	5R	0 - 0 - 10 - 6
	5T	0 - 0 - 9 - 7
	5Z	0 - 0 - 8 - 8
No. 6: Waste, stucco, or plaster..	6D	0 - 0 - 7 - 9
	6F	0 - 0 - 6½ - 9½
No. 7: Refuse or shorts...........	7D	0 - 0 - 5 - 11
	7F	0 - 0 - 4 - 12
	7H	0 - 0 - 3 - 13
	7K	0 - 0 - 2 - 14
	7M	0 - 0 - 1 - 15
	7-20	20 lb.per cu. ft.,loose measure.
	7-25	25 lb.per cu. ft.,loose measure.
	7-30	30 lb.per cu. ft.,loose measure.
	7-35	35 lb.per cu. ft.,loose measure.
No. 8: Sand.......................	8-40	40 lb.per cu. ft.,loose measure.
	8-45	45 lb.per cu. ft.,loose measure.
	8-55	55 lb.per cu. ft.,loose measure.
	8-75	75 lb.per cu. ft.,loose measure.
No. 9: Gravel and stone...........	9	75 lb. and over per cubic foot, loose measure.

The fiber is packed in jute bags of 100 or 125 pounds capacity marked with the grade letter or number and the manufacturer's name.

Arizona

The high cost of transportation to railways and heavy freight charges to markets render the sale of shorter-grade Arizona fibers unprofitable. Spinning fibers are therefore the principal products of the Arizona deposits. The smaller mines produce hand-cobbed crudes almost exclusively. The rock is mined and cobbed by the same workers on a contract basis. Cobbing is conducted in much the same way as in Canada.

Three of the larger mines have milling facilities. The largest mill, equipped with crushers, cyclones, and screens, produces No. 1. mill fiber 3/4 to 2-1/2 inches long; No. 2, 3/8 to 3/4 inch long; No. 3, 1/8 to 3/8 inch long; and No. 4, 1/8 inch and less. The products are graded according to tests made with a standard Canadian testing machine.

In one of the smaller mills the rock first passes through a jaw crusher followed by two sets of rolls. Two grades of fiber are separated by an impact screen. The shorter asbestos is treated with a small fiberizing machine and is cleaned and graded in a trommel 16 feet long and 4 feet in diameter.

Another small mill produces 5 grades of spinning fibers and a shingle stock. No grades shorter than shingle stock can be sold profitably.

A considerable quantity of rock containing spinning-fiber veins, which are difficult to cob by hand, are treated in these mills and yield what is known as mechanically cobbed crude fiber, an anomalous designation according to the Canadian definition of crude, which includes only hand-cobbed fiber. The claim is made, however, that the crude fiber can be graded by machine more accurately than by hand.

Vermont

The asbestos-bearing rock quarried near Eden, Vt., first is crushed to 5- or 6-inch size in a 24-by 36-inch jaw crusher and then discharged to a 36-inch belt conveyor, which carries the material to a 1,000-ton storage bin. When taken from storage it is crushed to 3- or 4-inch size in a 13-by 30-inch jaw crusher, passed through a rotary drier, and again crushed to 1- or 1½-inch size in a gyratory crusher, whence it is conveyed to a second storage bin. The product of the tertiary crusher is treated in a series of Jumbos or fiberizers like those used in Quebec, and the fiber is recovered by screening and air suction. After passing through dust removers and graders it falls into bins according to its length and is bagged in 100-pound burlap bags. Three principal products are manufactured: (1) Shingle stock, testing 0-2-10-4 or 0-1½-9½-5; (2) millboard, paper or molded brake-lining fiber testing 0-0-10-6; and (3) material suitable for roofing, paints, plastics, molded products, and boiler covering, testing 0-0-5-11. Occasionally a higher-grade fiber, testing

0-8-6-2, suitable for magnesia pipe covering is produced. Virtually no crude or spinning fibers are produced in Vermont.

Union of South Africa

Chrysotile. - At the New Amianthus mine, Barberton district, Eastern Transvaal, long-fibered chrysotile is hand-sorted and graded by natives as A and B, fiber over 1-1/8 inches long and fiber 3/4 to 1-1/8 inches long, respectively; both are designated as crudes. A third grade, E, consisting of hand-selected fiber down to a half inch long might be classed as crude.

Rock bearing the shorter fibers is crushed, dried, and reduced by rolls. The product of each set of rolls is sieved over 10-mesh screens, the fines going to waste. After passing through four sets of rolls the product is virtually pure fiber except for dust adhering to it. The asbestos is passed through a fiberizer to beat out the dust, then over a dust sieve, and finally over grading sieves. Two principal mill grades are made: F, 1/4 to 1/2 inch; and G, 1/5 to 1/4 inch. Grade F corresponds to Canadian fiber testing 0-4½-10-1½. The milled fibers are principally shingle and paper stocks. The mill has a capacity of 6,000 tons of rock a month.

At the Munnik-Myburgh mine in the same district 4 grades of hand-cobbed chrysotile fiber are designated as follows: IXL, over 3/4 inch; XL, 1/2 to 3/4 inch; X, 1/4 to 1/2 inch; and XX, 1/8 to 1/4 inch. Hand-cobbed fiber is graded in shaking screens.

Short fiber is treated in a mill with an elaborate flow sheet. Dried and crushed rock is passed through a series of rolls followed by grading screens. All five products obtained are passed through a regrading plant. The grades and their values, as shown on a Canadian standard testing machine, are as follows:

M1	2-11-2-1
M2	0-8½-6-1½
M3	0-3-10-3
M4	0-0-8½-7½
M5	0-0-4½-11½

The milled grades constitute about 95½ percent of the total fiber recovery.

Crocidolite. - Methods of milling and grading crocidolite vary greatly in different localities. In the Southern Belt of the Cape Provinces the workings are numerous, and many are relatively small. At the smaller workings the fiber is all hand-cobbed. It is often hand-sorted into grades according to length, but at the larger workings the hand-cobbed asbestos is graded by machinery. A hand-turned trommel made of perforated sheet iron or covered with wire netting usually is employed. The cobbed fiber from a series of workings may be shipped to a central screening plant where all asbestos 1/2 inch long or over is recovered, and the minus 1/2-inch product is taken to a mill for further crushing and grading. At one mill the rolls travel at slightly different speeds so as to subject the fiber to a tearing action. Double grading trommels are sometimes used. The inner cylinder has 1/4-inch holes and the outer 1/8-inch. Material passing the outer cylinder is waste, the oversize from the outer cylinder is designated grade SS, and the oversize from the inner cylinder grade S. The following grades are produced:

E: Over 2-inch cobbed fiber.
D: 1-3/4-inch to 2-inch cobbed fiber.
C: 1-1/4-inch to 1-3/4-inch cobbed fiber.
B: 7/8-inch to 1-1/4-inch cobbed fiber.
A: 1/2-inch to 3/4-inch cobbed fiber.
S: 1/4-inch to 1/2-inch milled fiber.
SS: Shorts, 1/8-inch to 1/4-inch milled fiber.

In the Northern Belt material over three fourths inch long is hand-cobbed. For many years the mill grades were not standardized, and the companies had difficulty in marketing their products. Later a large mill was erected at Kuruman, and the grades manufactured there established standards that offered such decided marketing advantages that other producing companies adopted them. In this mill rock carrying the shorter fibers is passed through crushers, heavy rolls, and disintegrators. The fiber thus separated is classified on grading screens. Tho following grades are made:

ES: Over 1-1/4-inch hand-cobbed fiber.
No. 1: 3/4-inch to 1-1/4-inch hand-cobbed fiber.
Also 2 grades of plus 3/4-inch discolored fiber -
No. 2: 3/8-inch to 3/4-inch milled fiber.
No. 3: 3/8-inch, or under, milled fiber.

Of the total fiber recovered about 13-1/2 percent is hand-cobbed and 86-1/2 percent milled. In both the Northern and Southern Belts about 9 percent of the total fiber is of spinning grade.

Crocidolite of the Pietersburg district, Transvaal, is passed through rolls, fiberizers, and grading trommels. Four grades are produced:

B: Over 1-1/4-inch.
A: 5/8-inch to 1-1/4-inch.
S: 1/4-inch to 5/8-inch.
Paper grade: 1/8-inch to 1/4-inch.

Amosite. - Because of its unusual length most of the amosite produced is hand-cobbed. The fiber thus freed from adhering rock is passed through a series of rolls and disintegrators and then graded on shaking screens or trommels usually into three grades. No. 1 is spinning fiber; No. 2 is used in the manufacture of rope, felts, and similar products; and No. 3 is used for asbestos-cement products, such as roofing slates and corrugated sheathing. The fiber is classified both according to length and color. The colors range from whitish gray to yellowish; the gray shades are considered the best. Most of the mills are small.

Rhodesia

The Rhodesian asbestos industry is centered at the large chrysotile mines of Shabani. To avoid damage to the fiber as much of it as possible is separated from the rock close to the working face; hence the hand-cobbing and bagging of crude fiber is an important part of quarrying and mining operations. Each cobbing boy recovers about 1,500 pounds of fiber a shift in open quarries and 1,000 pounds a shift in stopes. The cobs are said to average 40 to 50 percent fiber.

The quarry rock first is broken in jaw crushers and rolls, and the products are sorted on picking belts into three groups: (1) Rock containing little or no fiber, (2) rock containing large seams of fiber, and (3) fines and rock carrying small seams of fiber. Product 1 is left on the belt and conveyed to the waste heaps, product 2 is carried on a second belt to the cobbing sheds, and product 3 is conveyed by a third belt to the mill. Hand cobs from both the cobbing sheds and the quarries or stopes are fiberized and graded in one mill, and the fiber-bearing rock is reduced in another.

Some maintain that when fiber-bearing rock is kept wet until it reaches the mill it suffers less damage and is in better condition for milling than when it is handled and rehandled dry. After primary crushing in the mill the rock is dried either with steam-heated equipment or in rotary driers in which the products of combustion from wood fires are in direct contact with the rock. The dried rock is reduced in a series of small grinding pans operating like pug mills. Fiber is separated from rock with shaking screens and air suction in the same manner as in Canada. Undesirable brittle fiber is ground in the pans and passes through the screens with the waste rock. Fiber carried in the air current is deposited in a centrifugal settler, and the air passes on through the exhaust fan and dust trap to an outlet. The asbestos is taken to a grading mill, where it is cleaned further from dust and separated into the various market grades. Grading is done in hexagonal trommels.

Cobbed asbestos is fiberized, cleaned, and graded in a mill in which the equipment is modified to handle longer fiber.

In the Shabani area the tonnage of cobbed fiber ranges from 2-1/2 to 3-1/4 percent of the total rock mined. Total milled and cobbed fiber averages about 4 percent of the rock quarried. One must not infer that the rock is leaner than in Quebec, whererecovery is about 6 percent, because short-fiber material amounting to many thousand tons in Quebec is discarded as waste in Rhodesia.

Few data are available on the grades produced at Shabani or on the proportion of each grade. From 25 to 30 percent is spinning fiber, and most of the remainder is shingle stock. Fiber shorter than paper stock cannot be handled profitably because of the heavy transportation expense to markets. The longest spinning fibers, Nos. 1 and 2, are the only grades quoted in the United States market reports.

At the King's and Gaths' mines in the Mashaba district the asbestos is recovered by hand-cobbing only. The tonnage of marketable fiber obtained is 0.7 to 1.2 percent of the rock quarried.

Russia

In Russia crude asbestos is sorted in the quarry and cobbed as in Canada, but with increasing mechanization hand-cobbing has declined, and a larger proportion of the fiber is prepared mechanically. For many years the fiber was concentrated by hand-sorting in the quarries. Although recoverable fiber averages about 4-1/2 percent of total rock quarried the elimination of barren rock by hand-sorting so raised the grade that mill feed averaged about 22 percent of the fiber. During recent years mechanical mining equipment has replaced hand methods to a large extent, and the fiber is concentrated by hand-sorting on picking belts after the rock is crushed.

The preliminary stages of rock treatment are exemplified best in one of the newer mills, the "Gigant", which began operation in 1932. Rock from the quarry is conveyed to a storage bin and from that to a No. 9 Gates gyratory crusher, which reduces it to about 6-inch size. It discharges to a picking belt, where about 20 percent of the primary feed containing too little fiber to justify milling is thrown out as waste rock. The asbestos-bearing rock is reduced to 1-1/2- to 2-inch size in two No. 7 Gates gyratory crushers discharging to heavy shaking screens. The oversize from the screens passes to picking belts, where more barren rock is eliminated. The good rock from the picking belt is reduced to about 1-inch size in a jaw crusher and joins the undersize from the shaking screens in a wet-storage bin whence it passes to 3 rotary driers, which reduce the water content from about 8 to 1 or 2 percent. The product is conveyed to the dry-storage bin.

The most noteworthy feature of the preliminary milling stage is the concentration on picking belts. Because the serpentine tends to break cleanly along the fiber veins, effecting a more or less distinct separation of barren and fiber-bearing rock, conditions particularly favor this method of concentration. Of the original mill feed, consisting of 2,400 tons a day, about 1,440 tons are eliminated as waste, leaving only 960 tons for the later milling processes. Thus, picking belts save operators a great deal of useless milling.

In the more advanced milling stages the dried rock is passed over heavy shaking screens, from which four products are obtained: (1) Fiber removed by suction fans, (2) oversize rock conveyed to a set of rolls, (3) middlings that bypass the rolls and are carried to the next screen, and (4) fines conveyed to a Humboldt disintegrator. By means of a series of such rolls, screens, suction pipes, and disintegrators virtually all of the fiber is recovered. Fiber from the collecting hoppers is sent to a series of shaking screens for cleaning. The cleaned fiber is collected again by suction fans and classified by length in slowly rotating grading trommels.

The older mills employed a typically Russian method of milling. The rock was reduced in a series of rolls, and part of the fiber was separated from rock with trommels; the major separation, however, was made on inclined planes provided with suitable gaps. The fiber dropped through the gaps, and the rock fragments jumped over them. Ru Keyser[8] has described milling processes in some detail.

A large new mill designed to handle 2,000,000 tons of rock annually and produce 80,000 tons of fiber in 6 grades was nearing completion in 1934. This mill will give Russia a total milling capacity of approximately 175,000 tons of fiber a year.

Little information is available regarding the grades produced and the percentage of each grade. Estimates made in 1931 indicated that fiber one third inch or more in length constituted about 30 percent of the total output. Since that date, with increasing factory capacity for the manufacture of asbestos products, probably a larger proportion of the shorter grades is produced. Grades entering the German market in 1929 were designated as follows:

Grade 0: 1-1/2 inch or longer.
Grade 1: 3/4 inch to 1-1/2 inches.
Grade 2: 5/8 to 3/4 inch.
Grade 3: 3/8 to 5/8 inch.
Grade 4: 1/8 to 3/8 inch.
Grade 5: Less than 1/8 inch.

Price quotations of Russian fiber in the American market include Crude No. 1, Crude No. 2, Crude No. 3, and shingle stock.

Cyprus

In Cyprus the rock-bearing chrysotile asbestos is so decomposed that it breaks down readily into small sizes. Small quantities of hand-cobbed fiber are obtained. Rock reduced in the quarry by hand methods is screened to eliminate barren material over 18 mm (7/10 inch) and fines under 5 mm (1/5 inch); the intermediate product, which averages about one sixth of the total quarry output, is sent to the mills. The mill feed is crushed and passed over flat shaking screens and the fiber recovered by air suction. It is treated further to remove dust and to classify it according to length. Recovery of fiber is about 3-1/2 percent of the mill feed, and virtually the entire production is short fiber.

Milled asbestos is graded into three classes - standard, shorts, and fines. The standard grade, designated "shingle stock", is said to include about 75 percent of the production. The entire output is exported. Twelve mills were reported in operation in 1935. Their aggregate capacity is 25,000 tons of fiber a year of 6 working months. They are operated during the dry season only.

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[8] Ru Keyser, Walter A., Asbestos Milling in the Urals: Eng. and Min. Jour., vol. 134, no. 10, October 1933, pp. 415-419.

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Australia

The Lionel plant in Australia produces four grades, which are numbered in the reverse order from that generally practiced; the smaller numbers are applied to the shorter fibers. No. 1, the lowest grade produced, includes fibers about 1/4 inch long; No. 2, about 1/2 inch; No. 3, about 1 inch; and No. 4, 2 inches and over.

Anthophyllite Milling

Anthophyllite, a variety of amphibole asbestos, has been mined in a small way in the United States for many years. Small mills have been operated in Georgia, Montana, North Carolina, Oregon, Virginia, and Washington. As a large percentage of the rock treated is asbestos, fiberization and classification are the principal milling processes. The fiber is much weaker than chrysotile, and therefore severe treatment is to be avoided.

In one mill operated a few years ago the dried rock was broken in a gyratory crusher, whence it went to a hammer mill equipped with air suction for carrying off the loose fiber. This process was followed by reduction in a double-cage mill, the cages running in opposite directions. The fiber was removed by air suction; an enlargement in the suction pipe retarded the velocity of the air current, permitting heavy fragments of unopened fiber to fall. These fragments were returned through a trap to the cage mill in closed circuit. The fiber was classified with vibrating screens.

In another mill the dried rock is first reduced with a jaw crusher, followed by a set of rolls. The crushed asbestos rock is fiberized in a hammer mill equipped with an air separator. Coarse material is returned to the fiberizer, dust is collected in a dust chamber, and the fiber is conveyed to a bin that feeds into a packer. The fiber is packed in 100- or 200-pound sacks. Modifications of these processes are employed in other mills.

MARKETING

Asbestos is used in so many diverse products that its markets are numerous and widespread. It is used extensively in the United States, England, France, Germany, Belgium, Italy, Netherlands, Spain, Russia, and Japan. The last country has become an important buyer of roofing-grade asbestos. Russia at one time exported almost its entire production, but it recently has become an important manufacturer of asbestos products. Many other countries use smaller quantities. With greater diversity in use, expansion of automobile production, development of new types of building materials, and stronger demands for heat-insulation material the consumption of asbestos has increased steadily. In recent years mineral, slag, and glass wools have increased in importance as insulation, and although generally used in fields other than those in which asbestos is employed they are replacing asbestos to some extent.

Canadian asbestos generally is preferred by users in the United States, although African and Russian fibers may be substituted for many uses. Considerable quantities of the latter fibers are mixed with the Quebec product.

The principal Canadian producers sell direct to consuming industries and also to dealers and agents who distribute it to consumers. Sales frequently are made to consumers only after they have examined and approved samples submitted by dealers or producers. Canadian firms sometimes supply European customers with trial consignments of several tons, particularly if they are introducing new products. Sales are also made according to fiber length as tested and guaranteed by the producer. The larger manufacturers of asbestos products have their own testing machines and can check the producer's classification. The Canadian standard testing machine is used to some extent in Africa.

Asbestos is sold in 100-pound or 125-pound bags on a short-ton basis, bags included. Quotations are f.o.b. mines. The weight of a given volume varies with the length of fiber as the longer fibers are bulkier. The volume of a short ton ranges from 60 to 90 cubic feet. A minimum carload of fiber is 20 tons and of asbestic, 30 tons. Settlements usually are made on the basis of 2 percent discount within 10 days or 30 days net.

Before the World War Hamburg was the principal marketing center, but since that time New York has become the most important. The larger producers now have offices in New York, Hamburg, London, and other large cities.

Market requirements are based principally on fiber length, but strength, flexibility, color, chemical composition, and cleanliness may have an important bearing on use. The principal market outlets are indicated in the following brief summary of uses.

The longer and more valuable asbestos crudes and fibers, ranging upward from about $70 a ton, are used in manufacturing woven brake linings, textile fabrics, and asbestos packings. The next lower grades, ranging from about $25 to $70 a ton, are used in manufacturing rigid asbestos-cement shingles, lumber, and corrugated sheathing. Still shorter fibers are used in manufacturing paper and millboard, and the lowest-grade fibers are employed in heat-insulating cements, cold molded products, and fillers.

European imports from Africa are handled principally by dealers or agents. The importers pay cash or open a credit in South Africa and sell on credit to manufacturers. The latter concerns do not buy directly from producers because they are accustomed to buy on 3 to 6 months' credit, and importations are not made easily on such a basis.

Several of the largest asbestos organizations are of the vertical type; that is, they mine and mill the raw materials and fabricate finished products. At least three large companies in the United States are of this type, each having mines in Canada and factories in the United States. Turner & Newall, Ltd., controls nearly all of the asbestos production of Rhodesia and much of

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that of the Union of South Africa and has 20 large asbestos-products factories in England. The Russian industry is also of this type; the State controls both production of raw materials and manufacture of finished products. Because of this condition a substantial portion of the asbestos consumed never enters the open market.

Most of the world supply of raw asbestos is in exceptionally strong hands, and distribution is conducted in close and sympathetic collaboration with buyers, many of whom are also strong, well-organized concerns. Hence, new producers and new sales organizations are not likely to dislocate the market seriously. Furthermore, new organizations sometimes have difficulty in finding a market because consumers of asbestos ordinarily place orders 12 to 18 months in advance of actual needs. Centralized control by large units also makes possible the establishment of marketing agreements. Turner & Newall Ltd., having control of virtually the entire output of Rhodesia, was able in 1931 to consummate an agreement with Russia whereby orders were apportioned between European consumers and the market stabilized on a basis satisfactory to all concerned.

PRICES

Prices of Canadian asbestos have fluctuated greatly during the past 15 years. In 1920, because of war stimulation, prices skyrocketed to unprecedented heights, Crude No. 1 selling for more than $3,000 a ton. In 1921 the price dropped to less than half that amount, and by 1925 the highest grades were selling for only about one eighth of the price received in 1920. Table 1 shows, except for 1933 and 1934, the average price per short ton f.o.b. mine received by producers as reported to the Quebec Bureau of Mines. These figures generally are considerably lower than the average price quotations as given in Mineral and Metal Markets. Since 1932 the Canadian figures, unfortunately, are not presented in enough detail to show values by grades.

Price trends are shown graphically in figures 1 and 2.

Average quotations for Vermont asbestos, as given in Mineral and Metal Markets, are shown in table 2. Prices are per short ton f.o.b. mines.

Table 3 shows prices of Rhodesian and Russian asbestos per short ton, average quotations for the year, as shown in Mineral and Metal Markets. All prices are c.i.f. New York.

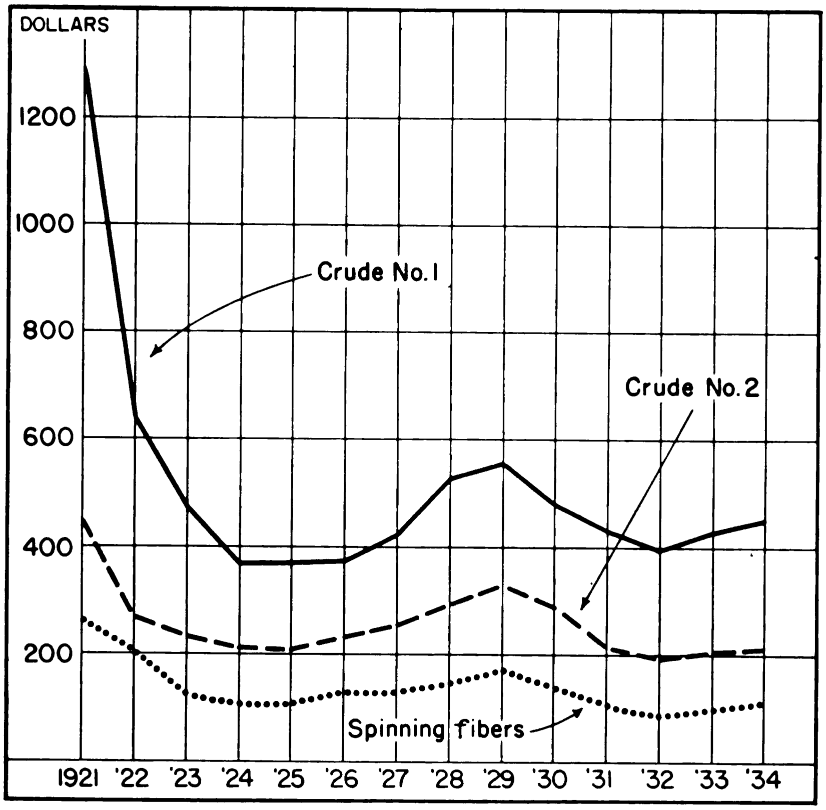

Figure 1.- Prices of Canadian crudes and spinning fibers, 1921-34. Data for 1921-32 from value of sales compiled by the Bureau of Mines, Province of Quebec. Data for 1933 and 1934 from price quotations in Mineral and Metal Markets.

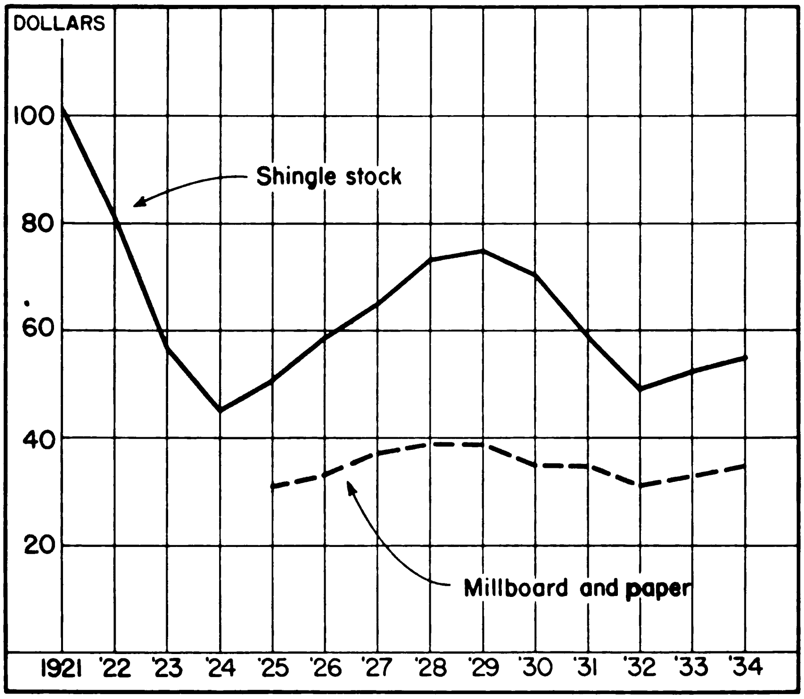

Figure 2.- Prices of Canadian shingle, millboard, and paper stocks, 1921-34. Data for 1921-32 from value of sales compiled by the Bureau of Mines, Province of Quebec. Data for 1933 and 1934 from price quotations in Mineral and Metal Markets. Figures for millboard and paper not available prior to 1925.

TABLE 1. - Average value per short ton of asbestos sold in Canada, 1921-34 1/

Year	Crude No. 1	Crude No. 2	Spinning Fibers	Shingle Stock	Millboard and paper stock
1921	$1,281.32	$ 446.91	$ 263.09	$ 101.75	2/ $ 31.19
1922	648.68	265.32	207.71	81.00	2/ 21.65
1923	472.60	237.29	123.37	57.05	2/ 22.01
1924	365.97	215.27	110.81	45.12	2/ 19.84
1925	364.96	206.12	106.43	50.78	31.03
1926	371.51	229.62	130.22	58.62	33.88
1927	423.65	249.59	129.32	64.80	37.82
1928	534.87	296.65	148.71	73.80	38.73
1929	557.38	331.82	177.30	75.26	38.56
1930	480.44	285.44	141.52	70.64	35.33
1931	431.46	216.35	107.22	58.72	3/ 34.66
1932	396.94	192.43	91.36	49.64	3/ 30.84
1933	437.50	206.25	100.20	52.71	3/ 32.71
1934	450.00	212.50	112.50	55.00	3/ 35.00

1/ Figures for 1921-32 from Quebec Bureau of Mines; for 1933-34, average of quotations, Mineral and Metal Markets.

2/ Paper and others.

3/ Paper only.

TABLE 2. - Prices of Vermont asbestos, 1931-34

Year	Shingle stock	Paper stock	Cement stock
1931	$ 50.71	$ 35.00	$ 20.00
1932	42.92	32.92	20.00
1933	42.92	32.71	20.25
1934	45.00	35.00	23.00

TABLE 3. - Average price quotations per ton of foreign asbestos

	Rhodesian		Russian			
Year	No. 1	No. 2	Crude No. 1	Crude No. 2	Crude No. 3	Shingle stock
1923	$361.11	$227.77				
1924	313.75	193.75				
1925	292.50	222.91				
1926	325.00	250.00				
1927	402.08	322.91				
1928	450.00	350.00				
1929	450.00	350.00				
1930	383.33	300.00	$210.00	$160.00	$ 50.00	
1931	304.17	204.17	227.50	184.17	113.54	
1932	187.50	131.25	213.54	163.54	125.00	
1933	186.67	136.67	212.50	162.50	125.00	$ 55.00
1934	210.00	160.00		162.50	128.75	$ 55.00

Asbestos-Products Plants

United States. - The United States leads all countries in the manufacture of products of which asbestos is an essential or important constituent. The Bureau of the Census listed 238 establishments in the United States making asbestos products in 1929, 208 in 1931, and 187 in 1933. The industry is centered chiefly in the North Atlantic States, notably in the Philadelphia (Pa.) and eastern New Jersey areas. Important factories are operated also in Cincinnati (Ohio), Chicago (Ill.), St. Louis (Mo.), and other midwestern cities; in the Southern States; and on the Pacific coast. Most of the output enters the domestic market; less than 5 percent in value is exported.

Table 4 shows the quantity and value of the principal asbestos products manufactured in the United States in recent years, as given in the Biennial Census of Manufacturers. The articles listed as "other products" are very numerous; some manufacturing companies sell more than 200 different articles. Many products included under the last four items in the table consist of various materials, including wood, steel, copper, cork, and rubber, in addition to asbestos, which may form a very small proportion of the total.

(Data from Bureau of Census)

	1929		1931		1933	
	Quantity	Value	Quantity	Value	Quantity	Value
Asbestos textiles and textile products:						
Brake linings........................feet	110,246,479	$16,447,438	56,059,659	$ 8,367,492	35,472,491	$ 4,545,006
Clutch facings......................pieces	38,096,113	3,910,727	21,340,773	1,796,761	18,857,760	1,601,934
Yarn..............................pounds	15,378,407	5,173,568	9,512,686	2,471,388	8,487,342	1,551,909
Cloth............................ do.	6,666,539	2,767,049	4,629,158	1,413,959	4,648,677	1,069,751
Tape, listings and tubular lagging do.	2,225,852	1,202,231	2,350,548	880,538	1,735,925	580,948
Packing.......................... do.	8,623,281	3,845,710	6,747,122	2,333,956	4,971,327	1,883,940
Gaskets.......................... do.	3,012,335	1,726,804	1,441,325	644,385	1,400,192	577,177
Other textiles..............................	-	1,088,466	-	630,770	-	812,535
Total textiles and products...............	-	$36,161,993	-	$18,539,249	-	$12,623,200
Asbestos building materials:						
Shingles.........................squares	894,164	$ 5,277,308	565,997	$ 3,266,054	408,256	$ 1,826,279
Lumber......................square feet	35,395,194	3,094,426	16,907,820	1,563,135	14,193,900	1,032,313
Other building materials..................	-	2,051,884	-	818,343	-	620,546
Total building materials..................	-	$10,433,618	-	$ 5,647,532	-	$ 3,479,138
Other asbestos products:						
Brake lining, molded.................feet	22,410,872	$ 2,534,646	24,180,184	$ 2,823,738	24,373,952	$ 3,422,593
Brake linings (kind unrecorded)..........	-	-	-	3,116,045	-	2,574,441
Pipe and boiler covering, air-cell...feet	67,331,323	4,657,666	39,083,826	2,755,354	19,554,455	1,137,283
Pipe and boiler covering other than air-cell.......................... do.	27,686,503	2,516,009	8,797,834	938,149	8,460,631	851,826
Pipe and boiler covering, 85 percent magnesia.......................... do.	23,959,209	3,045,324	19,323,303	2,511,795	10,818,354	1,457,211
Molded blocks, 85 percent magnesia.Bd.ft.	21,479,103	2,457,337	11,740,953	1,209,015	9,711,170	852,844
Millboard..........................pounds	7,280,221	345,375	-	-	-	-
Insulating cements................. do.	71,197,630	1,017,964	39,100,027	602,853	34,456,331	625,999
Table mats and protectors.......... do.	1,615,631	766,222	-	-	-	-
Other products 1/.........................	-	5,105,960	-	3,485,101	-	1,578,547
Gaskets other than asbestos textile 2/...	-	15,741,964	-	10,153,121	-	8,935,839
Metallic and semimetallic packings.......	-	-	-	2,110,725	-	1,809,361
Steam and other packing other than asbestos textile 3/....................	-	10,999,336	-	2,272,013	-	2,250,584
Total other products..................	-	$49,187,803	-	$31,977,909	-	$25,496,528
Grand Total..........................	-	95,773,414	-	56,164,690	-	41,598,866

1/ Asbestos paper and miscellaneous products; includes millboard in 1931 and 1933.
2/ Includes some gaskets that contain little or no asbestos.
3/ Excludes leather packings.

Canada. - For many years Canada exported almost its entire production of raw asbestos but lately has developed an important asbestos-products industry. In 1933, 11 plants were engaged in this line of manufacture. Four of them, in the center of the asbestos-mining district in Quebec, accounted for 77 percent of the total production. There are also 5 plants in Ontario and 1 each in Nova Scotia and British Columbia. The capital of these concerns was estimated at more than $1,777,000, and the selling value of the products at the works in 1933 was $757,626. The principal products are brake-band linings, boiler and pipe coverings, packings and paper and roofing.

Other countries. - Many of the data presented herein, except those relating to Great Britain, were assembled by Bruckner in 1929.[9]

The manufacture of asbestos products is an important industry in Great Britain. In 1929, 57 factories were operated by 35 companies, and the estimated value of their output was $28,163,000. Of the raw asbestos used 44 percent came from Rhodesia, 28-1/2 percent from the Union of South Africa, 21-1/2 percent from Canada, and small amounts from Cyprus, the United States, Italy, and Russia. The range of products is much the same as in the United States. About one fourth of the total output is exported.

In 1929, 32 factories in Germany made asbestos products, 17 of which were devoted chiefly to spinning, weaving, and braiding. Four factories made corrugated sheeting, pipe, roofing tile, and other asbestos-cement products. The raw asbestos is obtained chiefly from Russia.

In Austria, the original home of "Eternit", 9 asbestos-products factories were operated in 1929; asbestos-cement tile was the principal product of 4 factories.

In the same year 4 factories in France produced asbestos-cement roofing tiles and similar products; 9 plants were devoted chiefly to the manufacture of spun, woven, and braided products; 4 factories made high-pressure packings; and 2 factories made asbestos brake linings.

Nine factories in Belgium in 1929 were devoted principally to the manufacture of asbestos-cement goods, with a minor output of technical articles. In Italy 3 large factories and numerous small ones made chiefly asbestos-cement tiles and sheets. Thread, cards, cartons, textiles, and filter paper were also made in considerable quantities. Three factories in Czechoslovakia were devoted to spinning, weaving, and braiding; 1 made asbestos board; 4, high-pressure packings; and several, asbestos-cement tile. Most of the plants are small.

One factory established at Helsingfors, Finland, in 1923 manufactures "Eternit" products, packings, insulating materials, and fabrics. Both domestic and foreign asbestos is used.

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[9] Bruckner - The Continental Asbestos Industry: India-Rubber Jour., international issue, Oct. 31, 1929, pp. 19-21.

According to recent data about two thirds of the Russian output of asbestos is used in domestic factories devoted to the manufacture of asbestos products. Russia therefore is becoming an important factor in this industry. One very large factory at Leningrad makes asbestos-cement products, fabrics, paper, and insulating materials. As a result of research conducted at Leningrad by the Asbestos Institute several new products and processes of manufacture have been developed.

There are several factories in Poland, Hungary, Spain, and Switzerland. Several establishments in Japan make asbestos textiles, insulating materials, and asbestos-cement products. Evidently roofing is becoming an important branch of the industry in that country, because recently there has bean an unusually large demand for shingle-stock fiber.

FABRICATION OF ASBESTOS PRODUCTS

The manufacture of asbestos products involves many diversified and complex processes. Only a brief summary of the principal operations is presented herein because this report pertains primarily to raw materials.

Fabrics. - Crude fiber delivered to the manufacturing plant usually is crushed in a chaser mill, fiberized, and freed from rock impurities by screening and air separation. It is then ready to enter the various successive stages of manufacture into fabrics. Milled spinning fibers prepared by producers need not undergo this preliminary treatment.

The processes involved in the manufacture of fabrics follow in general those employed in spinning and weaving cotton, wool, or silk. Asbestos fibers differ mainly from those of organic origin in the nature of the surface. Wool fibers are covered with scaly bands known as imbrications, and cotton fibers are rough, twisted, and irregular. On the other hand, asbestos fibers have no nodules, twists, or irregularities on the surface that will enable one fiber to cling to another. They are more nearly akin to silk but are smoother and more rodlike. This smooth, slippery condition creates such difficulties in spinning that the manufacture of a 100-percent asbestos yarn is slow and costly; therefore a percentage of some other fiber, usually cotton, is added to act as a vehicle to carry the asbestos through the manufacturing processes. The proportion of cotton added varies with the character of the asbestos and with the nature of the finished product. It rarely exceeds 20 percent and with long-fibered Canadian asbestos may be as low as 2 percent.

Asbestos used in the manufacture of fabrics may consist of a mixture of varieties from different localities. The proportions depend upon the cost and quality of raw materials and the requirements of the finished product. Most manufacturers in America prefer Canadian fiber as a base, although many products now are made of African fiber alone. The blended fibers, together with the necessary addition of cotton,are mixed thoroughly with revolving beaters. Some manufacturers, however, introduce the cotton at a later stage.

Carding is the next step in the process of manufacture. Carding rolls are covered with leather and fitted with sharp steel bristles. They comb the fibers parallel and remove short fibers, bit of rock, and dust. After passing a succession of carding rolls the fiber emerges as a loose blanket, which may be turned 90° and passed through another carding machine. The blanket then is separated into rovings, which are gathered in a roll on a Jack spool and spun into yarn, as in ordinary textile mills.

Yarns are made in various sizes; a "5-cut" yarn measures about 500 yards to the pound and a "30-cut" yarn about 3,000 yards to the pound. When twisted exceptionally hard it is known as asbestos thread and used in sewing gas mantles, asbestos theater curtains, and asbestos clothing. The spindles of single-ply yarn are transferred to twisting machines and twisted into 2- or 3-ply yarn, which is wound on spools. Asbestos cord and rope are made by twisting together a greater number of strands.

Where yarn is to be used for brake bands or packings it usually is reinforced with fine copper, brass, or lead wire. Thus, for brake bands 3 strands of single-ply yarn and 2 strands of brass wire of gage nos. 0.006, 0.007, or 0.008 may be twisted together. For packings a single lead wire or 1 to 3 strands of brass wire are twisted with 2 or 3 strands of asbestos yarn. Products prepared in this way are known as "metallic yarns."

Yarns are woven into fabrics by well-known processes employed in cotton or woolen-textile mills. Asbestos cloth is used for theater curtains, fireproof clothing, and many other textile products. Single-ply asbestos yarn is also braided into tape. For electrical insulation it should contain not more than 7 percent carbon and not more than 14 percent cotton. Metallic yarn containing about 16 percent cotton is woven into strips for brake-band linings. Standard widths range from 1 to 6 inches and standard thicknesses from 1/8 to 3/8 inch. They are processed with rubber and other ingredients. The manufacture of brake-band linings for automobiles is the most important branch of the asbestos-products industry. As indicated in table 4, strips woven for this purpose in 1929 totaled more than 20,000 miles.

Asbestos packings are made in various ways. The yarn may be twisted or braided into valve-stem packings, the braided forms may be compressed into rings, or asbestos cloth may be cut into gaskets or other desired forms. They may be coated or impregnated with rubber compounds, oil, or flake graphite. Metallic yarn is used in some packings.

Shingles and lumber. - Roofing shingles are made of a mixture of approximately 75 percent portland cement and 15 percent shingle - grade asbestos. When manufactured by the so-called "dry process" the cement, asbestos, and coloring agent are mixed dry in a cylindrical mixer provided with paddles. The mixture is spread evenly on an 18-inch conveyor belt and sprayed with water at 180°F. Rollers compress it to the required thickness, and a rotary cutter separates it into individual shingles. Red, green, or blue-black slate granules may be sprinkled on the surface and rolled in lightly. The shingles are piled in stacks separated by steel pallets and squeezed in a hydraulic press at a pressure of 20,000 pounds per square inch, after which they are cured, trimmed, and punched for nailing.

Sheets of asbestos lumber up to 3 inches in thickness and 42 inches in width are made in the same way, but more time is required for compression and curing. Corrugated sheets are made by crimping flat sheets.

When the wet method is used cement shingle fiber and coloring matter are mixed with a large quantity of water, agitated thoroughly with a beater, and pumped to a paper machine, where sheets are built up to the desired thickness in successive laminations. Shingles thus formed are processed in the same way as those made by the dry method. Asbestos lumber is made by building to greater thickness and in larger sheets. Eternit products, both shingles and lumber, manufactured on a large scale in Austria since 1900 and during later years in the United States, are made by this process.

Paper. - Asbestos of paper-stock grade is mixed with a large amount of water to make a thin slurry, which is agitated thoroughly by 5-foot drums covered with slats. Starch, flour, or size and sodium silicate, derived partly from the overflow squeezed out of the paper at a later stage, are added to the slurry. This is then conveyed to a paper machine similar to that used in the manufacture of paper from rags or wood pulp. All particles of stone or other impurities are eliminated in a sand-catching and knot-removing machine. The sheets of paper pass between rollers to remove most of the water and are dried on hot cylinders and wound in rolls. If a 2-ply paper is desired 1 side of a sheet is coated lightly with sodium silicate, and the 2 sheets are run together over several hot rolls. Crimped paper is made by passing it over corrugated rolls. In the manufacture of air-cell pipe covering the tips of the corrugations are coated with sodium silicate, and a flat sheet is added. When this process is repeated a 2-ply, 3-ply, or thicker air-cell covering may be made. Asbestos paper has many other uses.

Compounded packings. - Certain types of asbestos packing are made by mixing clean, well-opened fiber with fillers, such as clay, barite, magnesia, iron oxide, graphite, or cellulose, and binding materials, such as gums, resins, lac, or rubber dissolved in benzine. High-quality sheets contain about 2 parts asbestos to 1 part filler. The mixture is molded into sheets of the desired thickness. Several sheets may be glued together and reinforced with copper or lead foil.

Magnesia insulation. - For the so-called "85-percent-magnesia" pipe covering a good grade of asbestos ranging from 0-6-6-4 to 0-5-8-3 is used - either chrysotile, blue asbestos, or amosite. Approximately 15 percent of fiber is mixed with 85 percent of basic magnesium carbonate derived from dolomite, magnesite, or bitterns at saltworks. These ingredients are mixed thoroughly with water and filter-pressed into cakes, which are dried for 3 days in steam-heated kilns. The blocks are then trimmed, cut in lengths, and bored to form hollow cylinders; these are sawed lengthwise, and the half-cylinder sections are rolled in pairs in glued canvas jackets. For ordinary use the walls have a maximum thickness of about 2-1/2 inches.

Asbestos cement. - A covering used widely for boiler insulation consists of short-fiber asbestos and a cementing material, such as plastic clay. The ingredients are mixed with water to form a paste which is applied with a trowel.

Cold-molded articles. - Increasing quantities of short-fiber asbestos are used in the manufacture of electrical fittings and household appliances. Mixtures of asbestos, gilsonite, cement, and oil are ground together and compressed in molds; these are baked in ovens, polished, and lacquered. Gilsonite imparts a brown color; if gray is desired the gilsonite is omitted.

Noncorrosive filters. - Amphibole asbestos, which in general is more resistant to chemicals than chrysotile, is washed, thoroughly fiberized, and otherwise prepared for use in Gooch crucibles or for other filtering processes employing strong acids and alkalies.